# DIASTROPHISM AND THE FORMATIVE PROCESSES. I[1]

## INTRODUCTION

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During the century or more throughout which a gaseous origin and an early molten state of the earth were accepted tenets a full system of doctrines relative to the formative and deformative processes of the earth was elaborated. In the earlier portions of the period these were largely based on the hypothesis of a thin crust floating on a liquid substratum. Later in the period various views of partial solidity grew up and modified the older tenets or replaced them with others. In more recent times essentially complete solidity has come into wider favor and been made the basis of more radical modifications. But these views of solidity were in the main derivatives from the original postulates of a gaseous origin merging into a molten state and they retained the presumptions appropriate to such earlier history. There thus ran through the whole system of tenets a thread of philosophy that shaped it in harmony with the initial assumptions. It is true that particular tenets were not always consistent with the system into which they were introduced, but this is only an inevitable incident. The solid earth of this philosophic lineage was usually of the type that holds rigidity to be but a function of viscosity. The tenets of formation and deformation built upon it embraced a doctrine of flowage of a slow secular sort directed by the principles of liquid motion restrained by viscosity. The presumption that such slow motion would take place under any appreciable stress if given time enough was a common tenet held widely and firmly. Specific doctrines of deformation and of secular tidal effects were worked out with great labor and skill on the basis of a visco-solid and even a visco-rigid earth. The tenets thus based on a solid and even highly rigid earth rounded

[1] Largely the results of studies pursued under the joint auspices of the Carnegie Institution of Washington and the University of Chicago.

out the older systems of doctrine founded on a more mobile earth into a fairly complete working scheme of inquiry and elucidation.

There were indeed individual instances in which the view of an elastico-rigid earth was entertained and yet regarded as springing from an earlier gaseo-molten state. But while thus entertained, this conception of an elastico-rigid earth was not carried out into a working system of doctrines consistent throughout with itself. There never grew out of it a panoply of tenets on which the geologist could base working hypotheses suited to his special problems on clear lines free from confusion with the tenets that sprang from a visco-solid earth. The instructor in geologic philosophy was never able to point the embryo geologists under his training to a set of views built distinctly on the working hypothesis of an elastico-rigid earth.

But aside from this deficiency, as already remarked, a quite ample system of tenets, with alternatives and divergences, has been developed, covering the full range of conceptions from the picture of an earth with a thin shell and molten interior through various grades of partial solidity up to dominant visco-solidity of a high order of rigidity.

So familiar have most of these tenets become that they often seem to stand by themselves quite independent of the hypotheses on which they were founded. By long currency they seem to have lost much of the speculative elements that really enter into them. This is not only a source of danger in itself but is likely to stand in the way of an impartial adjudication of less familiar conceptions that are not more speculative but merely seem to be so, and which are perhaps guarded by a more frank recognition of the speculative elements.

The strong support which new evidences from cognate sciences lend to the doctrine of an elastico-rigid earth, in distinction from a visco-solid earth or any form of fluidal earth, adds emphasis to the need for a system of tenets that are strictly loyal to the elastic principle. While the principles are thus loyal, the working hypotheses must obviously recognize that, though the earth may be dominantly an elastico-rigid body, it is not exclusively so. The gaseous and liquid elements are factors of moment and co-operate in

the great processes that form the earth-habit, but in this set of views it is to be assumed that they serve as subordinate elements and merely condition the dominance of elastic solidity.

The development of a system of tenets on the elastico-rigid basis is also invited by the grave objections that have arisen from new phenomena against the gaseous cosmogony and its sequences which lie back of the older system of tenets. The planetesimal cosmogony offered to meet these difficulties is founded on orbital mechanics and parts company with gaseous mechanics at the outset. Being thus dynamically diverse from the start, it has occasion for its own set of tenets. These need elaboration to meet the whole range of phenomena involved in the major problems of geology. The task of working these out has been steadily pursued but the labor is great, and progress, if guided by prudence and circumspection, is necessarily slow.

While many of these tenets of course have no immediate concern with the physics of the body of the earth and are not necessarily of the elastico-rigid order when they do, yet the dominant tendency from the nature of the hypotheses is in that direction. The planetesimal cosmogony opens the way at least for the evolution of an elastico-solid earth in the very mode of growth it postulates, though it does not exclude the possibility of a molten earth or even the probability that molten and gaseous states may dominate planets much more massive than the earth. With a body of the mass of the earth limited in its power to control the lighter gases, the trend of probabilities favors an essentially solid earth from an early stage of growth if not from the very beginning. An orbital organization may have dominated even the earth-nucleus of the parent nebula. At any rate, the long slow growth of the main mass of the planet offers rather strong presumption of a relatively cool solid accretion attended by heterogeneities of composition and differentiations of accession and crystalline organization that were never smoothed out by liquefaction but have remained of the same type as those now presented by the earth. An elastico-solid state is thus rather a matter of direct genesis than of subsequent derivation as is the case in the alternative mode of origin.

Following this hypothesis, therefore, one comes to a mature

earth with internal qualities closely like those of the accessible parts of the present body, and the working tenets that spring from this hypothesis most naturally are those founded on crystalline structure dominated by elastico-rigid properties. The conception is free from the inheritances of a liquid state with its inevitable assortments and systematic arrangements of material on the basis of specific gravity.

The conceptions of internal temperature and of vulcanism associated with this hypothesis by its author[1] are peculiarly hospitable to the development and maintenance of a solid crystalline state of the interior. They are relatively free from the postulate of very high temperatures. No occasion for a rise to the critical temperatures of rock-substance is offered and the dilemmas these bring do not trammel the problems of the planetesimal earth of the author. It is immune against the gaseous heart. The very mechanism of its vulcanism automatically forces to the surface the expansional factors that contribute to liquefaction and the gaseous state. The elements that, if retained, would lend mobility to its mass continually seek the surface, while those that contribute to stability and solidity remain within. The normal earth-habit under this hypothesis is conducive to a stable crystalline organization. This holds to as great depths as known methods of action may be safely projected. As balanced pressure contributes to solidity, it is a hazardous assumption that places narrow limits to the downward extent of solidity and the crystalline state.

Deep differentiations of specific gravity of moderate degree are natural results of a slow planetesimal growth under the conditions imposed by the early atmosphere and hydrosphere, in addition to the inequalities of infall. The inevitable deformations and gradational processes of the growing stages are presumed to have emphasized these inequalities, in certain respects, in modes of the same sort as those that affected all later history. These inherited inequalities of specific gravity are, perhaps more than any other agency, the governing power in shaping if not actuating diastrophic movements. This is the basis on which isostasy today does whatever it is competent to do toward a final equilibrium. How such a basis for

[1] "The Bearings of Radioactivity on Geology," *Jour. Geol.*, XIX, No. 8 (1911).

action could have arisen from a primitive fluidal condition is the task of those who postulate that state.

Under the planetesimal hypothesis, the earth grew slowly into the state which it still in the main retains, dominated by working methods of the same order as those that now prevail. No radical change of working tenets between the formative and the subsequent stages is required.

As already stated, the formative stages of the earth favored the retention within the earth-body of the stable crystalline compounds and the elimination of the unstable and mobile. It may be added that the formation of these stable compounds is favored by the conditions that lead to the eliminative process. These conditions were brought to bear on any given matter added to the earth first at shallow depths under moderate temperatures and pressures, and then successively at greater and greater depths, with higher pressures and temperatures, attended by the appropriate eliminations of unstable matter. This progressive action is held to distinctly favor the more and more perfect evolution of a crystalline earth-body progressively growing freer and freer of gaseous, liquefying, viscous, and colloidal elements.

Now crystals are the very type of elastico-rigid bodies. The permanent retention of their specific forms by means of definite elastico-rigid properties is one of their supreme qualities. We are not aware that there is any evidence that a crystal of rock undergoes any plastic or viscous deformation by reason of its own gravity in any known length of time. It may undergo change of form by molecular liquefaction and regelation or recrystallization, but it seems safe to challenge the citation of cases where crystals standing out from their attachments to the walls of crevices or cavities, though athwart the pull of gravity, have shown deflection or deformation, however long they may have stood in this position. The doctrine that flow will take place under gravitative stress if only time enough is allowed seems to be without the sanction of observation in this case, and equally without the sanction of sound theory when the nature of the case is precisely considered. The familiar reasoning is no doubt good for viscous bodies and for bodies in which a quasi-viscous condition can be induced by unbalanced

internal stresses. But in elastic bodies a specific amount of stress is prerequisite. The working tenets for elastic bodies must take account of this. There is a real plasticity and a quasi-plasticity.

The planetesimal hypothesis therefore lends its weightier presumptions to the belief that the earth, or at least its outer mass to great depths, is essentially an aggregate of crystals and derives from them, in a composite form, a measure of their solid elastic properties. The working tenets of this hypothesis are thus normally as distinctly elastico-rigid as are those of the gaseous genus of cosmogonies normally of the viscous type.

It has seemed worth while, therefore, to shape some of the studies in hand so that they will contribute, if they may, to the evolution of the working conceptions appropriate to masses of crystals of earth-dimensions under earth-conditions. Such articles may equally serve the more specific purposes implied by their titles. The discussions now in mind have grown out of studies on formative and on diastrophic processes. Time has changed the order of primacy from the formative of the early ages to the deformative of the later ages, at least it so seems to the student of present problems. We therefore chose the general title "Dia trophism and the Formative Processes" as a thread by which to preserve the semblance of continuity of purpose through the series of articles that may themselves seem more or less heterogeneous. The writer of this word of introduction will not be the sole contributor.